

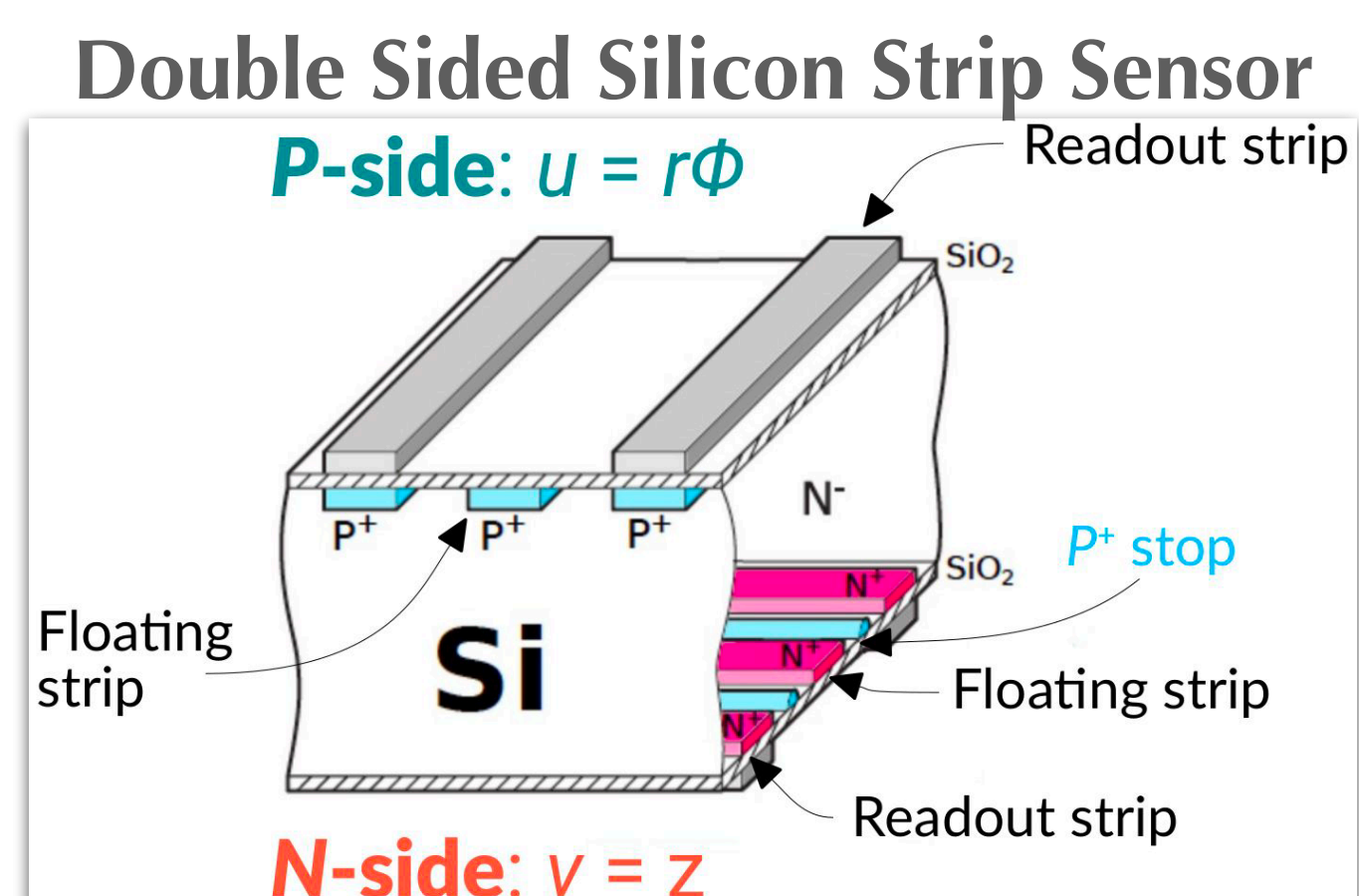
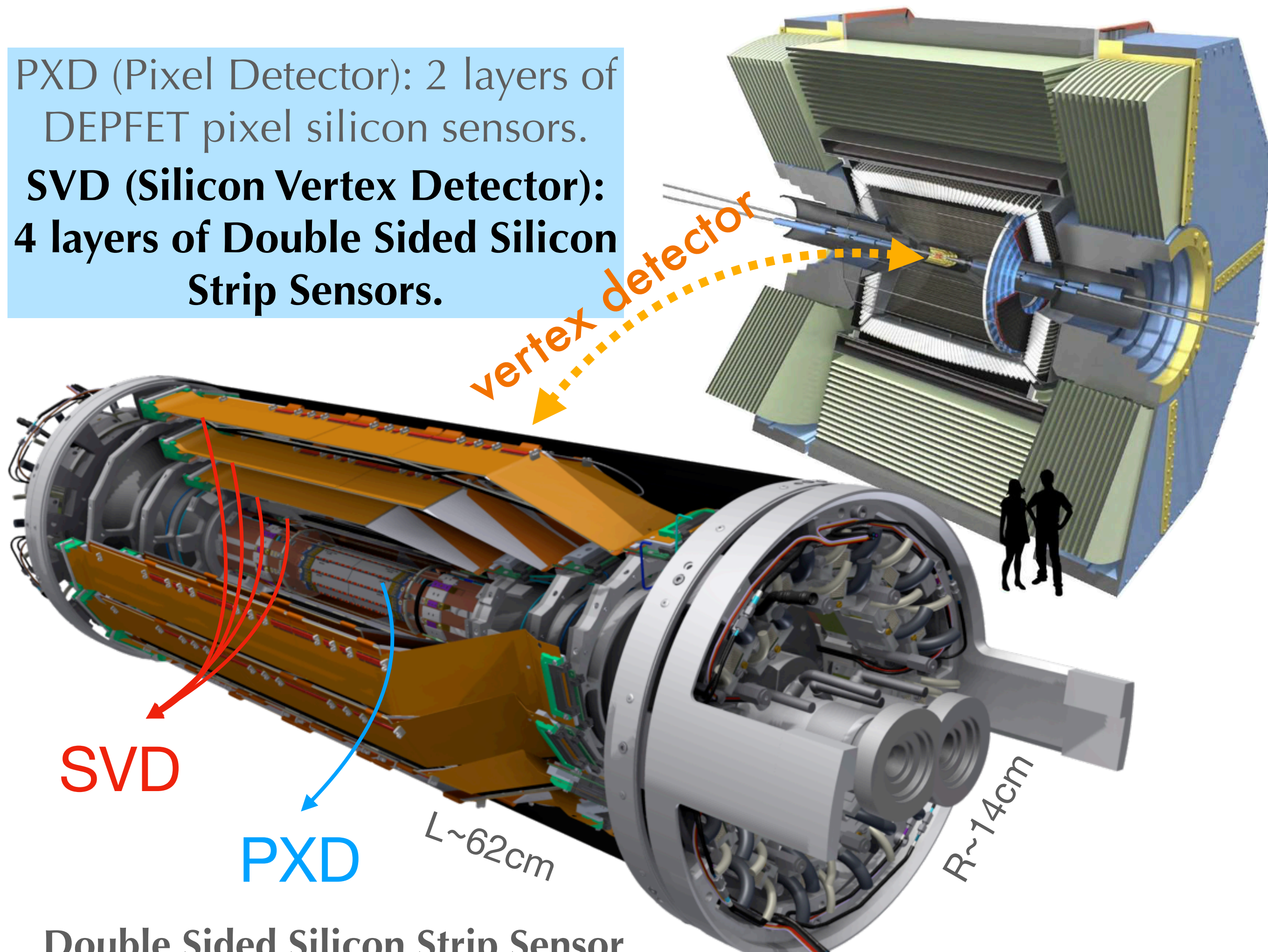
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Introduction

Belle II: Luminosity-frontier experiment searching for physics beyond the Standard Model at the e^+e^- SuperKEKB collider. World's record instantaneous luminosity $5.1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$.

PXD (Pixel Detector): 2 layers of DEPFET pixel silicon sensors.

SVD (Silicon Vertex Detector): 4 layers of Double Sided Silicon Strip Sensors.



Role of the SVD: precise vertexing; track extrapolation to PXD; standalone low-momentum tracking, and PID. Low material budget $\sim 0.7\% X_0/\text{layer}$, hit time resolution $\sim 3 \text{ ns}$

- Belle II data taking: **Run 1** 2019-2022 (with partial PXD) → long shutdown (full PXD installation = re-installation of the SVD) → **Run 2** 2024-... (PXD off since May 2024)

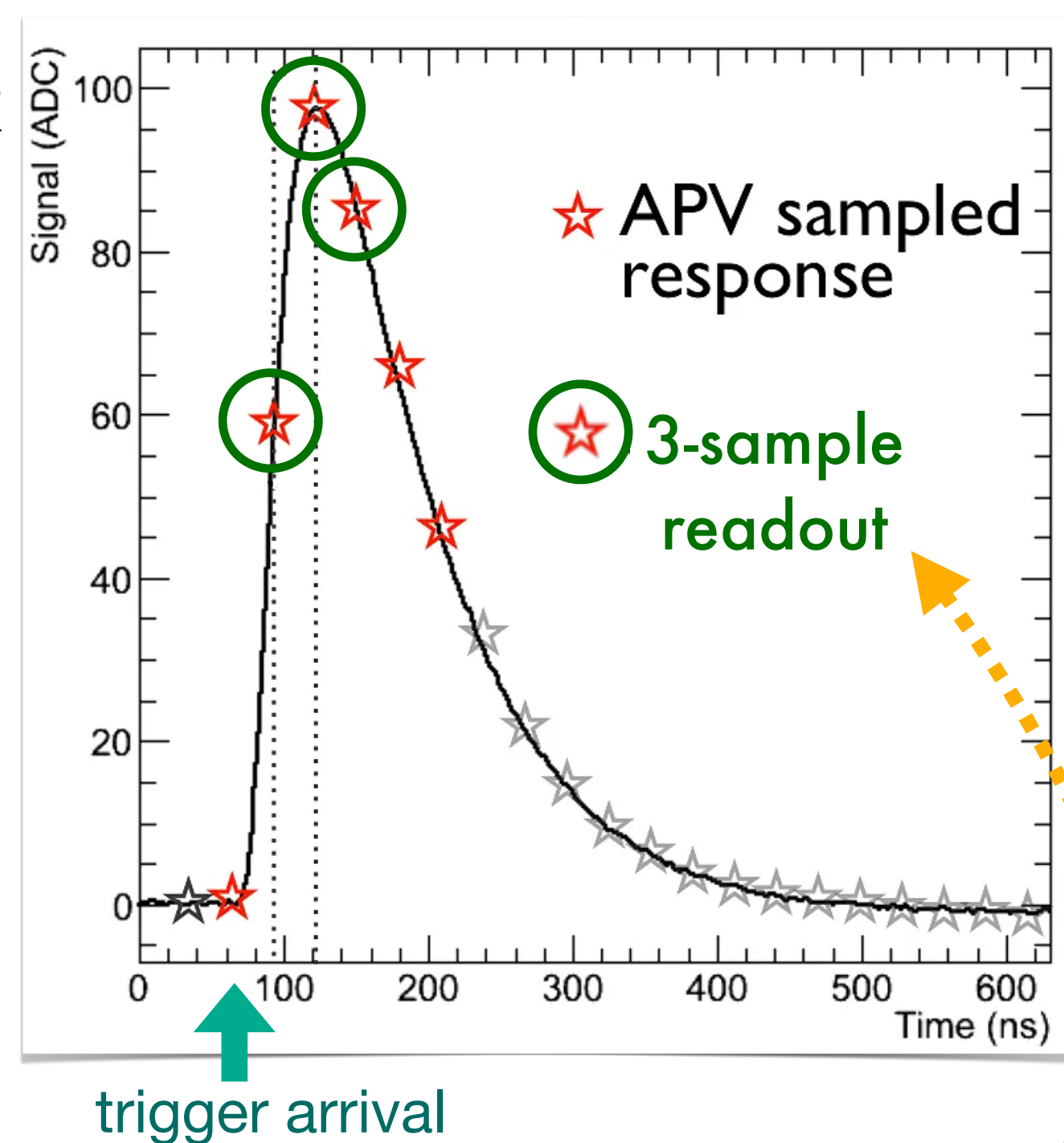
- Increasing beam intensity, relaxed beam-abort thresholds: higher beam background in 2024
 - Diamond monitoring system of beam losses

- SVD front-end electronics: APV25 readout chips

- 6 samples of analog output to reconstruct the waveform

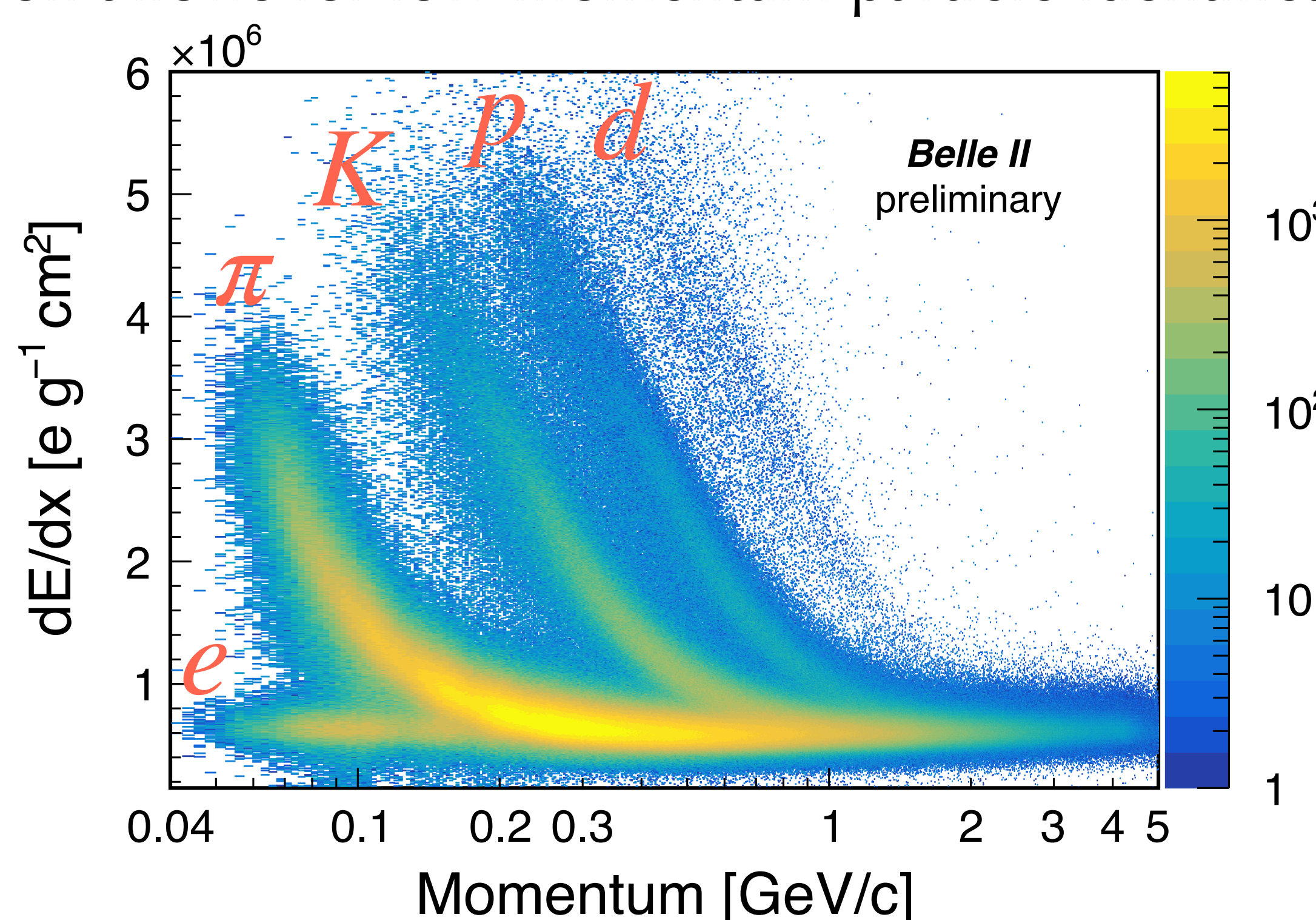
SVD reconstruction:

- Cluster:** collection of strips with signal-to-noise ratio above threshold
- For each cluster, measure: total charge, position, time



Particle ID with dE/dx

Measured energy deposit (dE/dx) by charged particles in silicon allows for low-momentum particle identification.

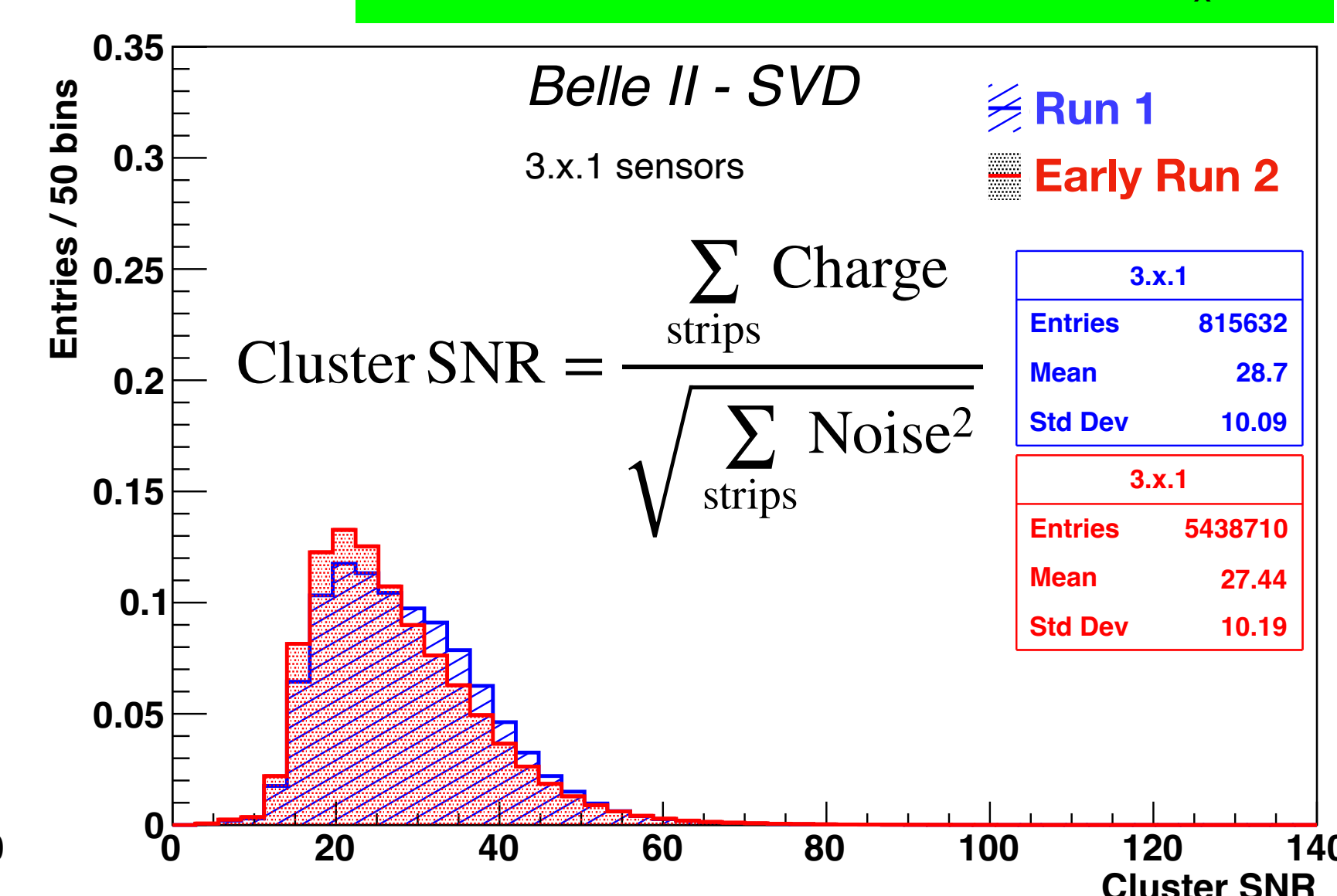
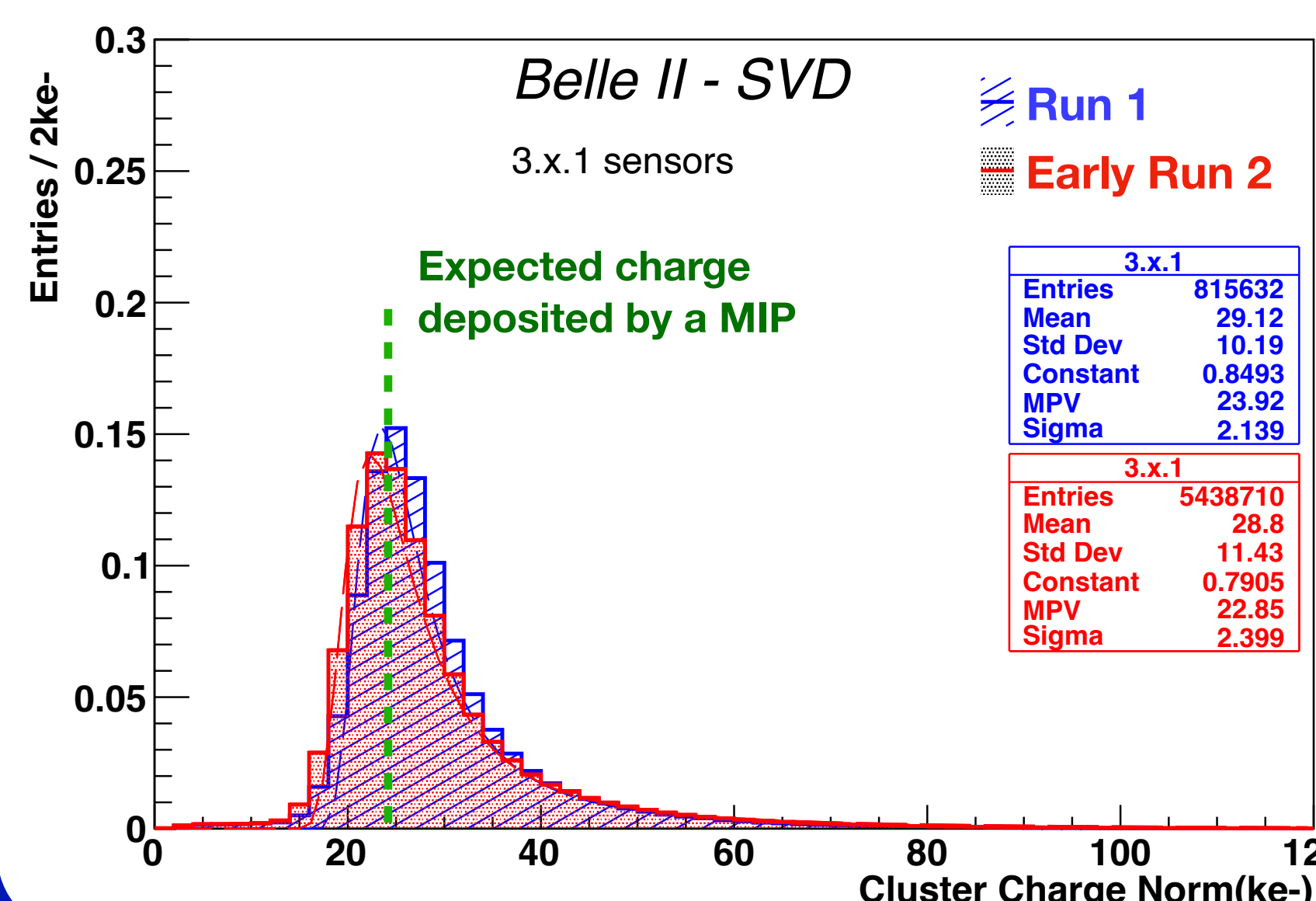
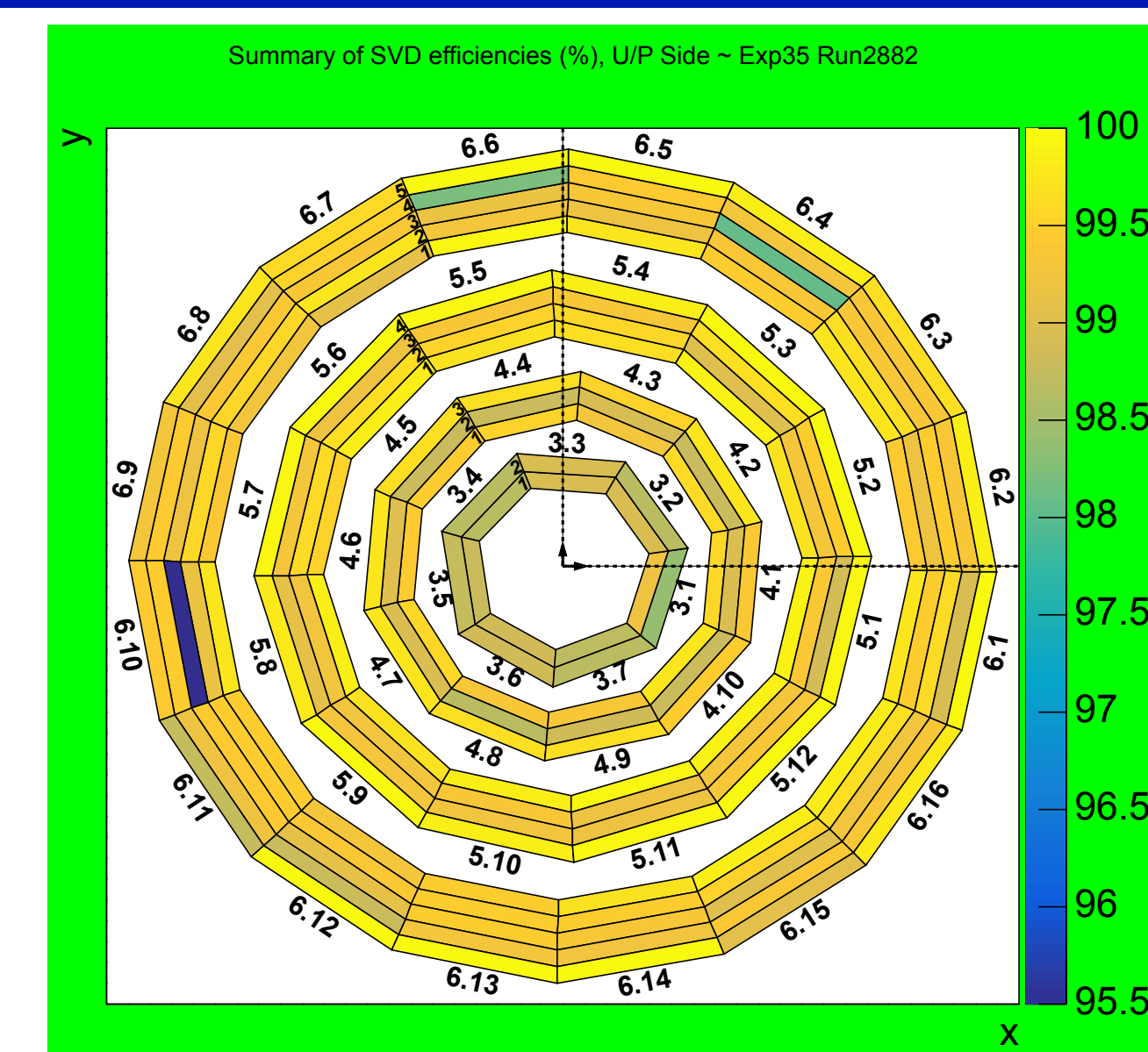


SVD operation in 2024

- Stable** operation despite challenging beam-background conditions
 - Radiation damage under expected level
- Masked sensors $< 1\%$ (fabrication issues mostly)
- Most frequent DAQ issue: APV25 chip misconfiguration due to Single Event Upset (SEU) due to high-dose beam losses
 - New firmware for faster SEU recovery (few s → 20 ms) developed for 2025

Performance in 2024

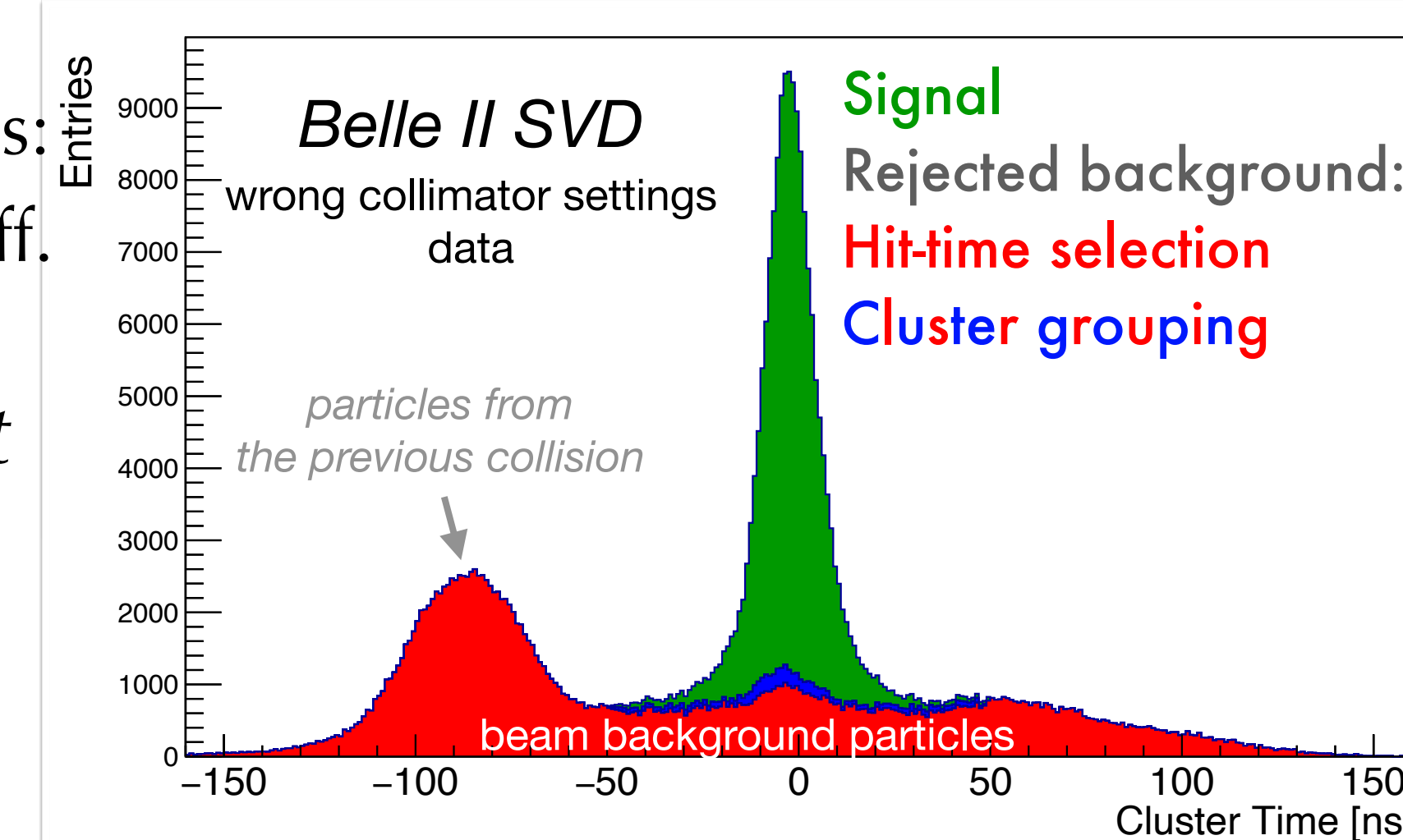
- Average hit efficiency **$> 99\%$ for most sensors** ($> 98.5\%$ inner layer), **stable** throughout the year
- Cluster charge and Signal-to-Noise Ratio quite stable compared to Run 1
 - slow SNR reduction due to radiation damage
- Innermost layer: position resolution $\sim 10 \mu\text{m}$, time resolution $\sim 2.9 \text{ ns}$.



Preparing for high-intensity operation

- SuperKEKB luminosity is expected to rise, goal $6 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ → increased **beam background**
- Hit **occupancy** (currently $< 1\%$) will rise, especially during injections
 - Fake track rate** needs to be kept under control
- Solution: use **timing** information!
 - e^+e^- collision products: SVD-hit time compatible with collision time
 - Background hits typically off-time

- Require $|t_{hit}| < 50 \text{ ns}$; $|t_{hit}^p - t_{hit}^n| < 20 \text{ ns}$: removes 50% background @ 99% signal eff.
- A more sophisticated event-by-event time-based cluster classification ("grouping")
 - Reduces fake-track rate by 40%, preserves $> 99\%$ of signal hits



- These measures will handle occupancy up to 5-6%.
 - Still, some room for improvement in using timing information.
 - An upgraded vertex detector is required for higher occupancy.

- Reduce the data size: mixed 3/6-sample readout instead of the 6-sample

These SVD time-based selections are not yet deployed in reconstruction, as background level is still quite low. However, the "grouping" classification is ready to be deployed if the occupancy in the inner layer increases to 2-3%.

References

- [1] Belle II SVD Collaboration, The design, construction, operation and performance of the Belle II silicon vertex detector; *JINST* 17 (2022) 11, P11042.
- [2] Belle II SVD Collaboration, Operational experience and performance of the Silicon Vertex Detector after the first long shutdown of Belle II; arXiv:2504.17715.